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Vindhyan Basin from the perspective of future hydrocarbon exploration – An integrated approach

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Abstract

Trap covered area of Vindhyan basin attracted less importance from hydrocarbon exploration point of view. Vindhyan exposed on eastern and western part are explored for last few decades. Geophysical data is sparse over these trap covered areas. Aeromagnetic data at an altitude of more than one kilometre, irregular spaced gravity data and a few MT stations data are used to bring out basement configuration to open up the basin for future hydrocarbon prospecting.

Integrated study shows that the basement in Chambal valley is dipping on either side of Singoli-Rajgarh ridge and may have sediment thickness of ~3km. It also shows that the gravity low near Ujjain may have accumulation of sediments up to 3 km. The Son valley is found to be dipping towards south and more than 5 km sediment are expected in northern part of north Narmada-Son fault at places below Tendu Khera gravity low, north and southeast of Bhopal.

A ridge like basement high connecting western part of Bundelkhand with granite expose area of western Hosangabad trending northeast-south direction is brought out. It may be this ridge which divides Vindhyan basin into Son valley and Chambal valley and not the Bundelkhand craton as believed earlier.

Introduction

Vindhyan Basin containing more than 5000 m thick sequence of sandstones, shales and limestones occupies an area of about 1,62,000 sq.km. of which about 80,000 sq.km. extends into the Ganga valley in the north and northeast beneath the tertiary sediments of the Himalayan foredeep.

The basin is bounded by the Narmada-Son Geofracture in the south, the Great Boundary Fault in the west, the Monghyr-Saharsa Ridge in the east and the Bundelkhand Massif and Indo-Gangetic Plains in the north. Bundelkhand Massif divides this basin into two parts – the Son Valley on the south-eastern side and the Chambal Valley where exposures occur from Agra (Uttar Pradesh) to Chittorgarh (Rajasthan) in western and north western side.

Deccan trap covered area of Vindhyan basin remains of least importance from hydrocarbon exploration point of view. Even the potential field data coverage in this area is very sparse. A gravity anomaly contour map of interval 5 milligals prepared and published by NGRI after merging GSI data has been widely used and referred by many earlier workers. Aeromagnetic data recorded at a flight height of 5000ft and 6800ft is also available to augment the integrated study.

The Southern part of the study area across Narmada–Son lineament abundant studies were carried out by institutions such as NGRI, IIG etc. In the periphery of the trap covered area published report of five Deep Seismic Sounding (DSS) profiles – 1. Hirapur-Mandala, 2. Khajuriakalan-Pulgaon, 3. Ujjain-Mahan, 4. Thuadara-Sindad, and 5. Nagaur-Kunjer is available for reference. Magneto Telluric (MT) profiles over Bundelkhand and across the CITZ is also available for reference.

The eastern part of this basin where Vindhyans are exposed has been explored by ONGC. In Son valley, few wells have been drilled (Fig. 1) on the basis of outcome of seismic campaigns in which presence of hydrocarbon is indicated in Rohtas limestone formations. Of late similar efforts were put in Vindhyan exposed areas of Chambal valley also. Three wells WE, WF and WG have been drilled based on seismic work under NELP regime. The well WG shows gas bearing column from a depth of 514 m to 1405 m. But the trap covered areas of Chambal valley remains unexplored even though gas seepage is reported.

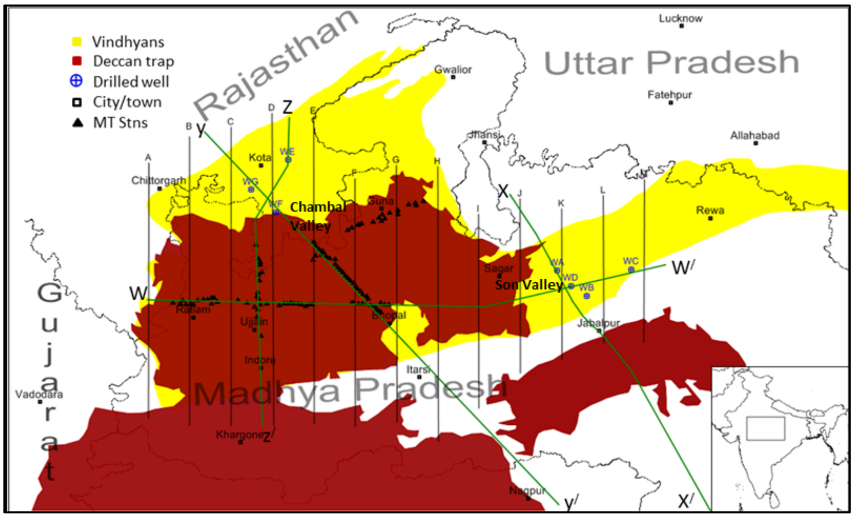

Fig. 1 Location map of the study area

Since last few years ONGC has carried out MT survey in trap covered areas of Chambal valley. More than 150 MT stations were acquired in this area. Along with MT data, gravity and magnetic data was also acquired.

Gravity data

Gravity anomaly map prepared by merging available vintage ONGC data, published data of NGRI and World Gravity Data 2012 shown in fig.2 is used for integrated study.

The north eastern corner shows gravity low up to -180 milligals which may be due to Ganga basin sediment together with root effect of the Himalayas. Delhi-Aravali trend, in the north-west and western part, shows a NNE-SSW elongated gravity high of up to 8 milligals which has a steep gravity low on either side. The Great Boundary Fault (GBF) has no gravity signature as the density of Vindhyan sediment is comparable with the basement/sediments in the up-thrown side.

The gravity signature of Bundelkhand massif is characterized by an east-west elongated gravity low of up to –70 milligals, it is surrounded by three trends of gravity high in the north, west and as well as in the south. The gravity high in the north extends from west of Kota to Allahabad where it meets with southern gravity high, Ratlam-Patna (RP). Another gravity high almost parallel to RP and a little south of it is Sardpur-Dewas-Sehore-Sagar (SDSS) ridge which seems to terminate at the edge of Son valley. These two ridges are intercepted by Singoli-Rajgarh (SR) ridge as western boundary of Bundelkhand massif. The Mukandra fault can be traceable upto north of Rajgarh beyond which it is not clear.

The southern part of South Narmada-Son fault (SNSF), where gravity highs are prominent between the rivers Narmada and Tapti is associated with Satpura Mountains. It is characterized by chain of gravity high trending east west till south middle part from where it turns towards north east–south west. Jabalpur gravity high, which has a maximum of -8 milligals, is also part of this chain. Many authors are claiming these gravity highs are due to a thick mafic body at the base of crust and presence of high density Mahakausals.

A gravity low of -86 milligals is seen over the Satpura basin known as Pachmarhi gravity low, it may be due to low density Gondwana sediments. A prominent gravity low of upto -98 milligals signifies the south Rewa basin.

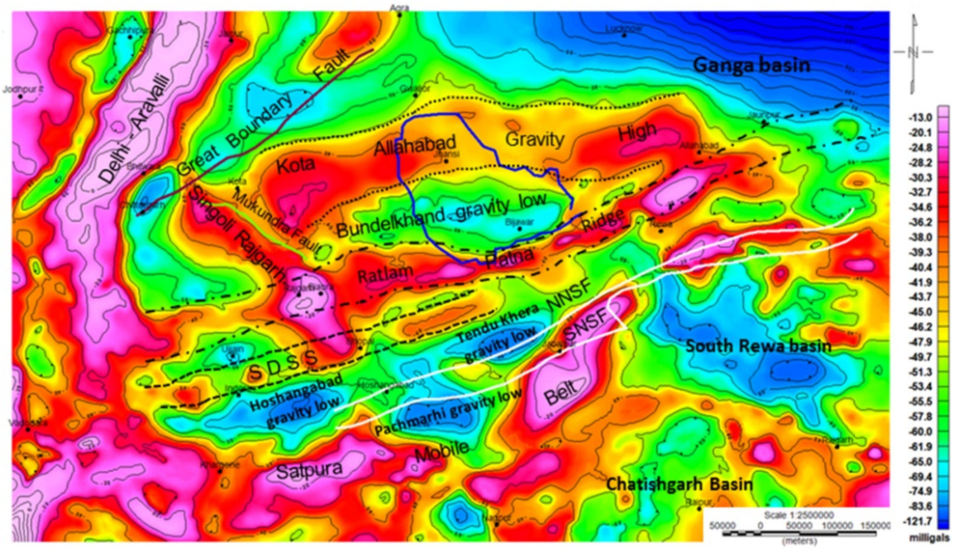

Fig.2. Bouguer gravity anomaly map. Blue continuous line marks Bundelkhand outcrop. Dark brown line shows the location of GBF and white lines show the NNSF and SNSF.

Integrated study

Integrated study of available G&G data is carried out along four profiles (fig.1) viz. WW/, XX/, YY/ and ZZ/. Of these, three profiles WW/, YY/ and ZZ/ are along Magneto Telluric profiles. The profile XX/ is along the Hirapur-Mandla DSS profile. A seismic section falling along this profile is shown in figure 5a.

Pseudo-section of MT data along YY/ (fig.3) shows a high resistivity layer at the top followed by low resistivity layer overlying a highly resistive basement. Both TE and TM show a low resistivity intrusion in the crust at lower frequencies near Site no. 27 and 28. The same is also seen in the phase section with a higher phase in this corresponding part. A fault like situation is suggested within the crust in this area.

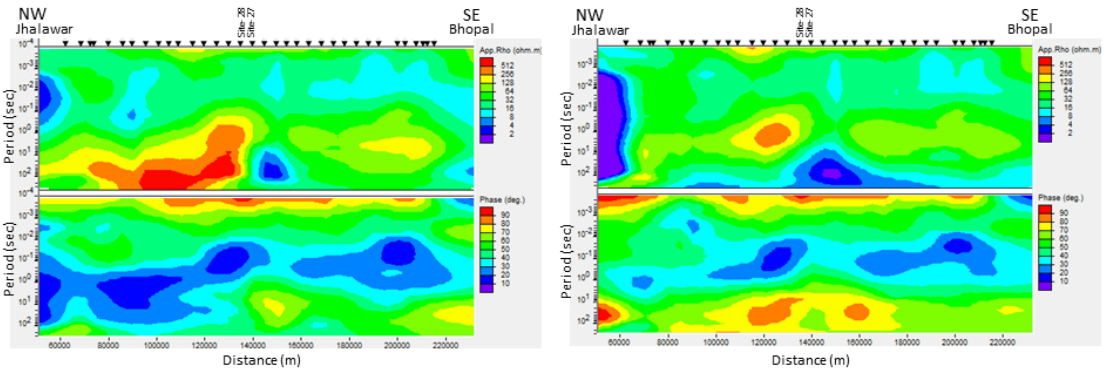

Fig. 3. Resistivity pseudo section along Jhalawar-Bhopal profile.

Figure 4 (left) shows the 2D inversion resistivity section of this profile. Though 1D inversion suggest basalt thickness in this profile vary between almost nil to 350m, because of large MT station spacing (~5km) 2D-inversion could not reconstruct the shallow features. Depth to basement is varying between 600 m to more than 5000 m along this profile shallowest near Rajgarh and deepest near Narsingarh, where Vindhyans are exposed. It shows a low resistivity intrusion in the crust near Biora.

Integrated gravity modeling was carried out in regional scale by constraining shallow information from Seismic, Well and MT data. Deeper information such as moho depths are taken from DSS data. A uniform density of 2.6 gm/cc for Vindhyan sediments, 2.4 gm/cc for Gondwana sediment and 2.2 gm/cc for recent sediments are taken. The basaltic trap is modeled with a density of 2.75 gm/cc while the mantle is of 3.0 gm/cc. The intrusive are only for producing the amplitude and its extent not caring its exact shape and density.

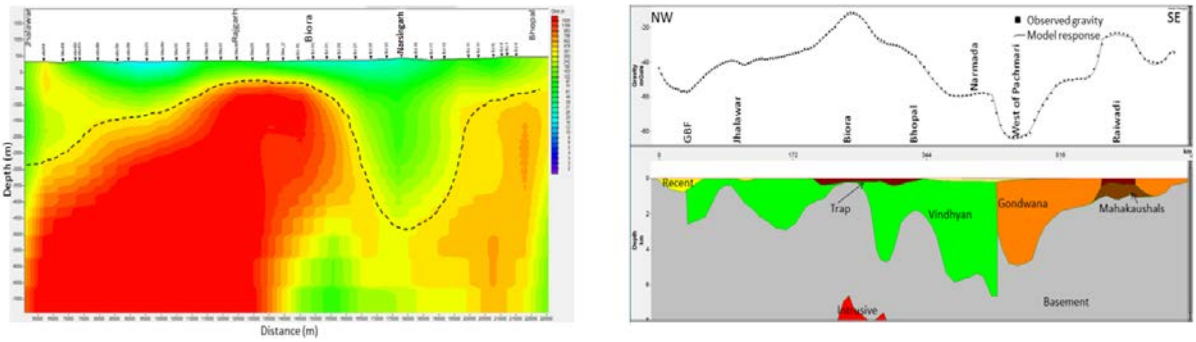

Fig.4. (Left) 2D inversion resistivity section dash line shows the inferred basement top.
(Right) Integrated Gravity modeling along YY$^{/}$ profile.

Apart from above mentioned constraints, depth computed from gravity and aeromagnetic data by deploying Spectral and Euler methods are used in predicting the possible basement depth. Also Euler depth computed in different window shows the causative of SR ridge is shallow while that of RP & SDSS ridge is having deeper roots.

The MT profile YY$^{/}$ is extended in either side to cover the entire basin from GBF to across Narmada Son lineament. Figure 4 (right) shows gravity modeling along this profile. The GBF is explained by low density alluvium and a dipping moho. In the eastern part of GBF the Vindhyan sediment thickness is expected ~2.6km. Rajgarh gravity high is explained by an intrusive as inferred by MT study. Depth to moho is found to be fluctuating between 45 - 48km along this profile.

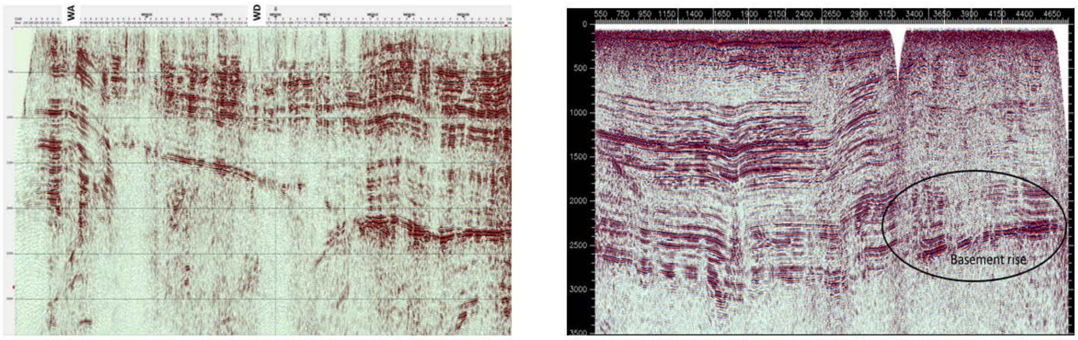

Fig.5.(a)Seismic section falling along the profile XX$^{/}$ (b) Seismic section along PP$^{/}$ in fig.6.

Integrated gravity modeling shows maximum thickness of Basaltic trap is around 380m in this profile. Shallow basement depth ~200m may be expected around Biora town. A thick layer of Vindhyan sediments ~ 5km may be present below the trap covered areas between Biora and Bhopal. More than 6km of Vindhyan sediment may be expected in the Narmada valley. Low gravity in the west of Pachmari is explained by lower density Gondwana sediments, which may accumulate upto a thickness of 4.8 km in this area.

Similarly integrated gravity modeling is carried out along other profiles WW$^{/}$, XX$^{/}$ and ZZ$^{/}$. The information obtained from these profiles is used for gravity modeling along 13 more profiles. These profiles (A, B….M, in fig.1) spanning across the trap covered area of Chambal valley and Son valley, are taken at an interval of ~50 km in north–south direction. Based on these integrated gravity modeling a basement contour map is prepared and shown in figure 6.

Basement contour map shows that the gravity low south of SR ridge may have sediment thickness of ~3km. The gravity low near Ujjain may also have sediments upto 3km thick. Maximum Vindhyan sediments are expected at places Tendukhera gravity low and South East of Bhopal where basement depressions are prominent. This basement depression is also extending towards north of Bhopal showing possibility of thick sediment ~5 km in this area.

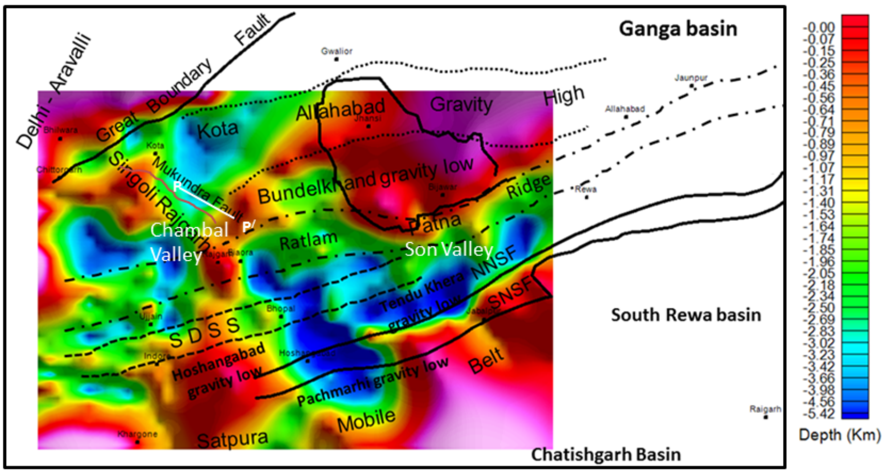

Fig.6. Basement top contour map prepared from findings of integrated study. (Colour not shown in the scale bar has no value).

In general Son valley is dipping towards south while the Chambal valley has basement dipping in either side of SR ridge. The eastern and north eastern part of Kota shows a basement depth upto ~3 km.

Gravity modeling shows that a ridge like basement connecting western part of Bundelkhand (exposed) with granitic expose area of western Hosangabad passing through Rajgarh. A part of this ridge can also be seen in seismic section of profile PP/ shown in fig.5b.

Conclusions

Integrated gravity modeling shows depressions in many places in the trap covered areas of Vindhyan basin. The Western and Central part of Madhya Pradesh may have 2-5km thick sediments which will be good target for hydrocarbon exploration.

It also shows that a ridge like basement high connecting western part of Bundelkhand with granitic expose area of western Hosangabad, passing through Rajgarh. It may be this ridge (basement high) which separates Vindhyan basin into Son Valley and Chambal valley not by Bundelkhand craton as believed earlier.

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